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Age of the Last Major Scabland Flood of the Columbia Plateau in Eastern Washington

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Pumice layers of set S from Mount St. Helens can be correlated with certain ash beds associated with young flood deposits of the channeled scabland. The correlation points to an age of about 13,000 ^{14}C yr B.P. for the last major flood to have crossed the scabland. Until recently, the last major episode of flooding was thought to be closer to 20,000 yr B.P., an age inferred chiefly from the relation of the flood to glacial events of the northern Rocky Mountains. Several investigations within the last few years have suggested that the last major flood occurred well after 20,000 yr B.P. Tentative correlations of ash beds of the scabland with set S pumice layers, the relations of flood and glacial events along the northwestern margin of the Columbia Plateau, and a radiocarbon date from the Snake River drainage southeast of the plateau all indicate an age much younger than 20,000 yr. The postulated age of about 13,000 yr B.P. is further supported by a radiocarbon date in the Columbia River valley downstream from the scabland tract. Basal peat from a bog on the Portland delta of Bretz, which is a downvalley deposit of the last major scabland flood, has been dated as 13,080 ± 300 yr B.P. (W-3404).

INTRODUCTION

The last great Pleistocene flood to sweep across the channeled scabland of the Columbia Plateau (Bretz, 1923, 1969) has not been closely dated, chiefly because of the scarcity of carbonaceous material in the flood deposits. Fryxell (1962) obtained an older limiting radiocarbon date of about 33,000 yr for the last episode of scabland flooding. In addition, his date of about 12,000 ^{14}C yr for the Glacier Peak ash that overlies scabland flood deposits (Fryxell, 1965; Powers and Wilcox, 1964) provides a younger limiting date. Fryxell (1962) assumed that advances of Cordilleran ice lobes east and west of the Cascade Range were approximately synchronous and estimated an age range of 15,000 to 20,000 yr for "the last few scabland floods" (Fryxell, 1962). Richmond *et al.* (1965) reported that the last great scabland flood occurred near the end of early Pinedale time of the northern Rocky Mountains. Chiefly on the basis of that evidence, Bretz (1969) inferred an age of about 20,000 yr B.P. for the last major scabland flood, and Baker (1973, 1976) estimated its age as 18,000 to 22,000 yr B.P. Waters (1933), Bretz *et al.* (1956), and Baker (1973) also suggested that a later flood, perhaps at about 14,000 yr B.P., was confined to the Columbia River Valley.

More recently, several investigations have indicated that the last major flood is younger than 15,000 to 20,000 yr B.P. Waitt (1972, 1977) inferred that the last scabland flood occurred after the Cordilleran ice retreated northwest of the plateau. Rigg and Gould (1957) had previously shown that the Cordilleran ice west of the Cascade Range had retreated before 13,500 yr B.P., and Waitt noted that, if the Cordilleran lobes east and west of the Cascades were contemporaneous, the latest flood must have occurred after 13,500 yr B.P. Mullineaux

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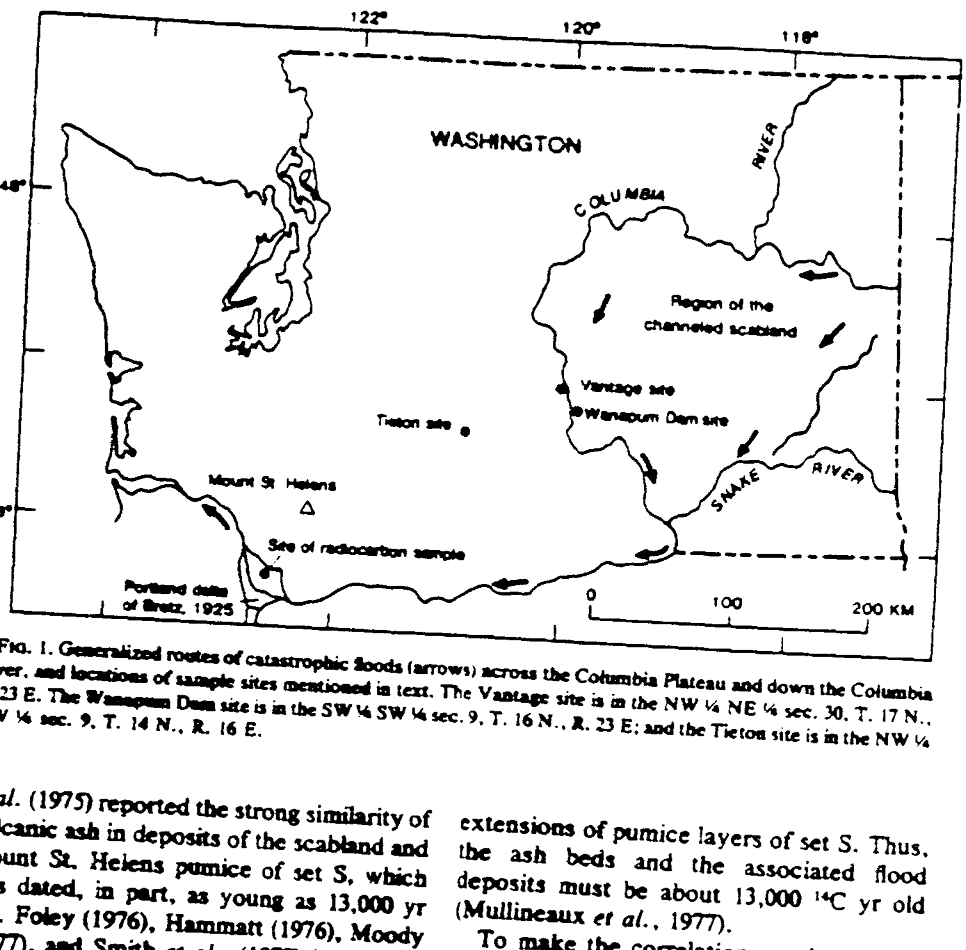
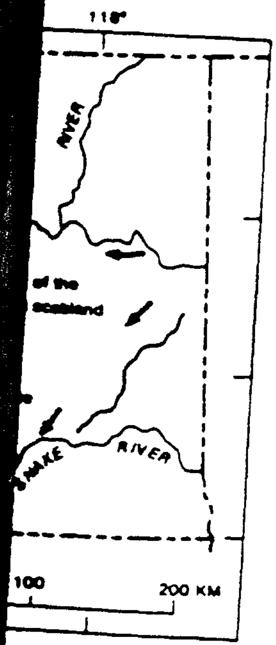


FIG. 1. Generalized routes of catastrophic floods (arrows) across the Columbia Plateau and down the Columbia River, and locations of sample sites mentioned in text. The Vantage site is in the NW ¼ NE ¼ sec. 30, T. 17 N., R. 23 E. The Wanapum Dam site is in the SW ¼ SW ¼ sec. 9, T. 16 N., R. 23 E; and the Tieton site is in the NW ¼ NW ¼ sec. 9, T. 14 N., R. 16 E.

et al. (1975) reported the strong similarity of volcanic ash in deposits of the scabland and Mount St. Helens pumice of set S, which was dated, in part, as young as 13,000 yr old. Foley (1976), Hammatt (1976), Moody (1977), and Smith *et al.*, (1977) have all at least tentatively correlated ash layers associated with scabland flood deposits with set S pumice. In addition, Hammatt *et al.* (1976) reported a scabland flood that, on the basis of a radiocarbon date in the Snake River drainage, "may date to 14,000 years B.P."

The ash beds associated with deposits of the last major flood offer an excellent means of assigning a relatively precise radiocarbon date to that flood, if those ash beds can be correlated with ash layers that are closely dated by radiocarbon elsewhere. We have concluded that certain ash beds in flood-related deposits are definitely downwind extensions of pumice layers of set S. Thus, the ash beds and the associated flood deposits must be about 13,000 ^{14}C yr old (Mullineaux *et al.*, 1977).

To make the correlation, we have compared petrographic and chemical characteristics of ash beds in flood-associated deposits near Vantage and Wanapum Dam along the west edge of the plateau (Fig. 1) with similar data for the several groups of upper Pleistocene pumice layers that are known near Mount St. Helens (Fig. 2). We also sought out exposures of set S ash at intermediate points between the volcano and the Columbia Plateau. As a further check, we investigated the age of the peat that immediately overlies the Portland delta of Bretz (1925), which is a downvalley deposit of the last major scabland flood. The peat has been dated as 13,080 ± 300 yr B.P. (W-3404).



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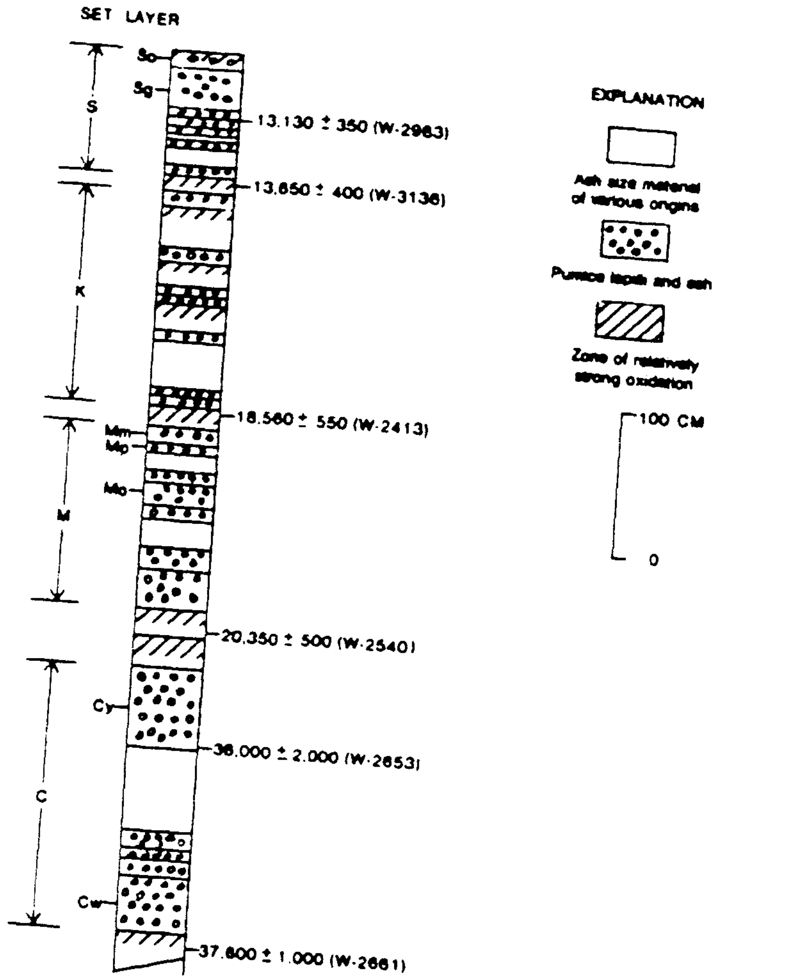

FIG. 2. Diagrammatic section of upper Pleistocene pumice deposits from Mount St. Helens showing stratigraphic horizons of selected radiocarbon samples that have been dated. Thicknesses shown for pumice layers are representative for a distance of about 10 km from the volcano summit in the northeast to east directions.

The present investigation was begun by Fryxell and Wilcox, who examined and sampled ash at many sites, especially in the western and central parts of the plateau. That investigation, however, was cut short by Fryxell's death in 1974. Mullineaux has studied the stratigraphy and age of the Mount St. Helens ejecta at and near the volcano. Ebaugh carried out the microprobe analyses, and Rubin was responsible for dating the radiocarbon samples.

ASH LAYERS IN DEPOSITS ASSOCIATED WITH FLOOD GRAVELS

Thin beds of white, pumiceous volcanic ash are widespread (Fryxell, 1972; Brown, 1973; Gustafson, 1976; Hammatt *et al.*, 1976; Moody, 1976) in sands and silts called slack-water deposits (Bretz *et al.*, 1956; Baker, 1973) that are associated with gravels of the last major scabland flood. The slack-water sediments have also been referred to as back-water and back-flood deposits by Bretz (1929, 1969) and as Touchet Beds by Flint (1938). Some investigators (e.g., Gustafson, 1976) have proposed that certain slack-water deposits are significantly younger than the last flood to cross the scabland. We believe, however, that the sediments containing the ash beds either were laid down during that flood, as interpreted by Bretz (1929, 1969) and many others (e.g., Baker, 1973, Moody, 1976), or were deposited shortly enough after the flood that any difference in age would be within the limits of error of radiocarbon dating.

In outcrop, many of the ash layers are striking in that they appear as couplets and triplets; that is, two or three successive ash beds are separated by nonvolcanic sediments that apparently were deposited rapidly and are only a few centimeters to a few tens of centimeters thick. These ash beds seem to have originated from at least three closely timed explosive eruptions.

The ash layers in the slack-water sediments contain abundant phenocrysts of cummingtonite. Cummingtonite is uncommon in volcanic ejecta, but it is abundant in ejecta of late Pleistocene age from Mount St. Helens volcano (Fig. 1) Wilcox, 1965; Mullineaux *et al.*, 1972, 1975). Mount St. Helens, therefore, is regarded as the probable source of the ash beds in the slack-water deposits.

Cummingtonite phenocrysts, however, are characteristic of pumice from at least four different Pleistocene eruptive episodes of Mount St. Helens. Moreover, more than one catastrophic flood, each with possible associated slack-water sediments, occurred during the Pleistocene (Bretz, 1969; Bretz *et al.*, 1956; Hammatt *et al.*, 1976; Richmond *et al.*, 1965). Thus, cummingtonite-

TABLE 1

CHARACTERISTIC Fe–Mg PHENOCRYSTS IN UPPER PLEISTOCENE PUMICE DEPOSITS FROM MOUNT ST. HELENS AND FROM ASH BEDS IN SLACK-WATER DEPOSITS NEAR VANTAGE AND WANAPUM DAM[a]

	Cummingtonite	Hornblende, green	Hornblende, brown	Orthopyroxene	Olivine	Biotite
Set S						
Layer So	A	A	C	C		
Layer Sg	A	A	C	M		
Other	A	A	C	M		
Set K	A	A	M	M		
Set M						
Layer Mm	M	A	M	C		
Layer Mp	C	A	M	M		
Other	A	A	M	M		
Set C	A	A	M, C	M	M	M
Beds near Vantage						
Upper	A	A	C	C		
Lower	A	A	C	M		
Beds near Wanapum Dam						
Upper	A	A	C	C		
Middle	A	A	C	M		
Lower	A	A	C	M		

[a] Proportions of Fe–Mg suites (rough estimates): A, abundant, >25%; C, common, 10–25%; M, minor, <10%.

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Olivine	Biotite
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	M

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bearing ash layers in slack-water sediments may represent more than one eruptive episode. Foley (1976) and Hammatt (1976), for example, have reported cummingtonite-bearing ash beds of two different ages in sediments adjacent to the plateau. Just how many of the four groups of cummingtonite-bearing pumices from Mount St. Helens are represented by ash beds on the plateau can be determined only by additional work.

CORRELATION OF SCABLAND ASH LAYERS WITH SET S EJECTA

The ash beds near Vantage and Wanapum Dam might conceivably be correlative with any one of four groups of cummingtonite-bearing pumice layers from Mount St. Helens (Fig. 2). At the volcano, pumice layers older than set S (Fig. 2) have not been named (Mullineaux *et al.*, 1972, 1975). They can now be subdivided further, however, and additional sets of pumice can be designated (Fig. 2). The oldest, set C, contains several pumice beds, all of which apparently are well over 30,000 yr old. Set M is a stratigraphically well-defined group of at least seven pumice layers that probably were erupted during a short time between about 20,000 and 18,000 yr ago. Set K contains several pumice layers that are preserved only locally, perhaps because the climate was so cold and wet that slopes were relatively unstable when the pumice was erupted. Relatively little is known of their stratigraphic sequence, age, or distribution.

Approximate age, stratigraphic relations, and mineral content are criteria by which correlation of ash layers of the scabland and set S can be readily tested. The ash beds at Vantage and Wanapum Dam clearly date from the last major glaciation because they occur in deposits that are associated with floods caused by catastrophic emptying of Glacial Lake Missoula during that glaciation (Richmond *et al.*, 1965). Their close stratigraphic spacing suggests that they were ejected by a series of closely timed eruptions. Cummingtonite and hornblende are abundant in the Fe–Mg phenocryst suites in all the ash beds at Vantage and Wanapum. In addition, orthopyroxene is plentiful in the uppermost bed at each site (Table 1).

Of the four groups of pumice layers at Mount St. Helens that might be correlative with the ash beds at Vantage and Wanapum Dam, set C seems to be much too old. Pumice layers of set K were deposited during the last major glaciation but probably not in rapid succession, and none is known to contain a significant amount of orthopyroxene (Table 1). Set M and set S also were erupted during the last major glaciation, and the eruptions that formed both sets apparently occurred in rapid succession. Cummingtonite and hornblende characterize Fe–Mg phenocryst suites of both sets, and orthopyroxene is plentiful in the uppermost layer of each set (Table 1). From these criteria, either set M or set S could be correlative with the ash beds at Vantage and Wanapum Dam.

Mineralogic differences, however, distinguish set S pumice from that of set M. Although the phenocryst suites of the two sets are similar, their proportions of green to brown hornblende differ markedly (Table 1). Green to brownish-green hornblende phenocrysts whose α indices are less than 1.660 are abundant in all pumices of both sets. Brown to greenish-brown hornblendes whose α indices are greater than 1.660 are present in set M pumice, but they generally make up only a small percentage of the total hornblende in any sample (Table 1). In set S pumice, however, brown to greenish-brown hornblendes whose α indices are greater than 1.660 are plentiful, and they generally make up 30 to 50% of the hornblende in a sample (Table 1). Generally, brown hornblende is nearly 10 times as abundant in set S pumice as in set M pumice. Although some mineral proportions may change downwind from a volcano because of selective sorting, the proportions of brown to green hornblende should not change, because the size, shape, and density of the various hornblende grains are very

TABLE 2

CA, FE, AND K IN GLASS SHARDS FROM UPPER PLEISTOCENE PUMICE DEPOSITS FROM MOUNT ST. HELENS AND FROM ASH BEDS IN SLACK-WATER DEPOSITS NEAR VANTAGE AND WANAPUM DAM[a]

Location[b]	Sample	Layer	Ca (%)[c]	Fe (%)[c]	K (%)[c]	Ca:Fe:K ratio
Mount St. Helens	74W102	So	0.92 ± 0.05	0.84 ± 0.08	1.56 ± 0.10	28:25:47
	74W101	Sg	1.07 ± 0.13	0.94 ± 0.06	1.54 ± 0.15	30:27:43
	8-12-71-8	Mm	1.00 ± 0.10	0.84 ± 0.07	1.44 ± 0.18	30:26:44
	8-12-71-9	Mp	0.99 ± 0.09	0.81 ± 0.03	1.49 ± 0.08	30:25:45
Vantage	68W66	Upper	0.97 ± 0.05	0.85 ± 0.07	1.54 ± 0.14	29:25:46
	68W67	Lower	1.11 ± 0.06	0.86 ± 0.06	1.39 ± 0.10	33:25:42
Wanapum Dam	69W44	Upper	1.03 ± 0.04	0.82 ± 0.10	1.52 ± 0.25	30:25:45
	69W45	Mid	1.11 ± 0.09	0.81 ± 0.05	1.35 ± 0.12	34:25:41

[a] The data were collected on an ARL-EMX microprobe at the U.S. Geological Survey in Denver, Colorado; they are relative to obsidian standard U of A 5831 (Westgate and Fulton, 1975) corrected for background with reference to quartz, supplied by D. G. W. Smith. The probe was operated at 15 kV with a sample current of 15 nA (quartz), defocused to 5-μm beam width.

[b] Locations are shown in Fig. 1.

[c] Values are means ± SD.

similar. Thus, hornblende proportions downwind from Mount St. Helens should be similar to those at the volcano.

Another difference between the two sets can be seen in the abundance of cummingtonite in their uppermost layers. The uppermost layer of set S contains a much higher proportion of cummingtonite relative to hornblende than does the topmost bed of set M (Table 1).

The proportions of brown to green hornblende and of cummingtonite to hornblende in the ash beds at Vantage and Wanapum Dam match those of set S rather than those of set M (Table 1). Thus, petrographic evidence seems adequate to select set S rather than set M as the correlative of ash beds at Vantage and Wanapum Dam.

In the field, we have found set S ash layers at many sites between Mount St. Helens and the Columbia Plateau. In addition to many sites close to the volcano, ash beds were sampled at three places at distances of about 30, 50, and 100 km from Mount St. Helens, approximately along a line between Vantage and the volcano. The easternmost (Tieton) site is roughly two-thirds of the distance from Mount St. Helens to the Vantage locality (Fig. 1). At each site the stratigraphic relations suggest a rapid sequence of ashfalls, brown hornblende phenocrysts are plentiful, and the uppermost cummingtonite-bearing ash layer contains plentiful orthopyroxene. The ash beds become thinner and finer grained as distance from Mount St. Helens increases. Thus, it is clear that multiple layers of set S extend across the Cascade Range toward the Vantage and Wanapum Dam sites.

Preliminary microprobe analyses show a strong similarity in the composition of glass in ash from the Vantage and Wanapum Dam sites and in pumice from sets S and M (Table 2; Fig. 3). They fail, however, to distinguish clearly between set S and set M. Smith and Westgate (1969) and Smith *et al.*, (1977) have pointed out that the elements potassium (K), calcium (Ca), and iron (Fe) are sufficient to distinguish some ash beds from Cascade volcanoes from certain others. For comparison, K, Ca, and Fe contents of each sample (Table 2) can be converted to proportions whose sum is 100%, and those proportions can be plotted on a ternary diagram (Smith and Westgate, 1969; Fig. 3). Table 2 and Fig. 3 show the scatter and

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K (%)†	Ca:Fe:K ratio
.56 ± 0.[illegible]	28:25:47
.54 ± 0.1[illegible]	30:27:43
.44 ± 0.18	30:26:44
.49 ± 0.08	30:25:45
.54 ± 0.14	29:25:46
.39 ± 0.10	33:25:42
.52 ± 0.25	30:25:45
.35 ± 0.12	34:25:41

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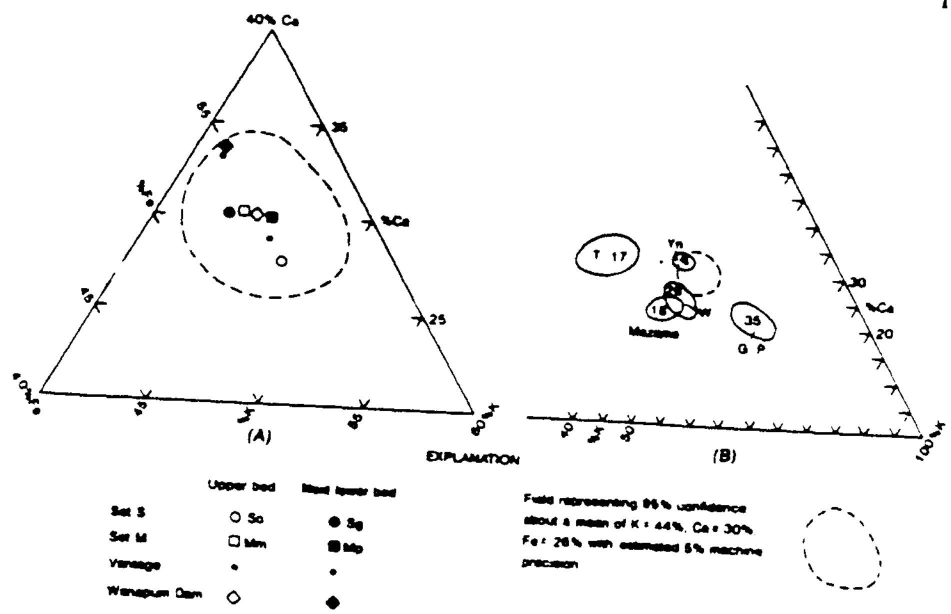

FIG. 3. (A) Electron-microprobe measurements of relative proportions of K, Ca, and Fe in glass shards from upper Pleistocene pumice deposits from Mount St. Helens and from ash beds in slack-water deposits near Vantage and Wanapum Dam. (B) the 95% confidence field from A is compared with data from Smith *et al.* (1977) for (T, W, Yn) Mount St. Helens tephra, Mazama tephra, and (G. P.) Glacier Peak tephra, upper, middle, and lower units. The number of samples is shown for each tephra.

overlap of points for our samples from sets S and M as well as for ash from Vantage and Wanapum Dam. The distribution of these points is roughly the same as scatter related to the precision of our microprobe technique at a 95% level of confidence; that is, the scatter is about what would be expected from repeated testing of a single sample using that technique. Thus, our sample data for sets S and M are not statistically different from each other at the 95% confidence level, and we cannot confidently correlate the ash beds at Vantage and Wanapum Dam preferentially with either set S or set M on the basis of the microprobe analyses. Our measurements, however, did yield higher proportions of K relative to Ca and Fe for layer So, the uppermost bed of set S, than for the underlying layer Sg (Fig. 3). We measured the same relation between the upper and lower beds at Vantage and the upper two beds at Wanapum Dam. In contrast, the proportion of K relative to Ca and Fe for the uppermost bed of set M is lower than in the underlying layer. Thus, the probe data are consistent with a correlation of set S with the ash beds at Vantage and Wanapum Dam.

We conclude, mainly from stratigraphic and petrographic data, that the ash beds at Vantage and Wanapum Dam belong to set S. How many other "couplet" and "triplet" ash layers in slack-water sediments of the plateau belong to set S, however, is yet to be determined. Investigations by Smith *et al.* (1977), Moody (1977), Foley (1976), and Hammatt (1976) indicate that set S ash beds can be identified at several other sites on and near the plateau.

AGE OF SET S EJECTA

From early studies at Mount St. Helens, set S was reported to be between about 18,000 and 12,000 yr old (Mullineaux *et al.*, 1972). Later, a sample of charred wood from a pyroclastic flow within set S and below at least two beds of the set was determined to be 13,100 ± 350 yr old (W-2983). On the basis of that date, the youngest beds in the set were estimated to be about 13,000 yr old, or perhaps even slightly younger (Mullineaux *et al.*, 1975). Two additional samples, from peat layers that respectively underlie and overlie all set S layers present at a site 50 km northeast of Mount St. Helens, have been dated at 13,650 ± 350 (W-3136) and 12,120 ± 350 (W-3133) yr B.P.

No evidence has been found to suggest that a long time elapsed between eruption of any two successive beds of set S. Oxidation is noticeable only at the top of the set, and this oxidation occurred after 13,000 yr B.P. but before deposition of overlying deposits dated at about 12,000 yr B.P. (Mullineaux *et al.*, 1975). Lack of significant oxidation of lower beds of the set suggests that no interval of as much as a thousand years elapsed between eruption of any two beds of set S.

Stratigraphic relations and radiocarbon dates indicate that eruption of set S took place over no more than about a thousand years. Moreover, the close spacing of layers suggests that the entire set could have been erupted within a very short time, perhaps as little as a few days or weeks. We suggest, therefore, that all of set S was erupted about 13,000 ^{14}C yr B.P.

AGE OF FLOOD DEPOSITS NEAR PORTLAND

Although material suitable for radiocarbon dating has not been obtained from the flood deposits on the Columbia Plateau itself, such material is abundant on the surface of the so-called Portland delta described by Bretz (Bretz, 1925; Trimble, 1963; Fig. 1). The delta was formed by the last major scabland flood as it continued down the Columbia River Valley. The delta is an appropriate place to date the flood because the Portland area was not glaciated and probably was humid and densely vegetated. Revegetation of the delta surface should have occurred quickly after the floodwater receded, and peat probably began to accumulate in ponds on that surface very soon after the flood.

Our date is derived from peat taken from the base of a bog described by Rigg (1958) as the Manor peat area No. 2. It lies on the surface of the delta a short distance north of Vancouver, Washington, in the SW ¼ SE ¼ sec. 7, T. 3 N., R. 2 E., at an altitude of approximately 60 m above sea level. The bog site appears to be high enough to have been above any flood later than the last scabland flood. Later floods (Waters, 1933; Bretz *et al.*, 1956; Baker, 1973) have been described as being confined to the narrow Columbia River Valley in eastern Washington; the valley of the Columbia near the bog locality is much broader and should have carried any later floods without high water sweeping over the bog site.

Peat from the basal 2 cm of the bog has been dated as 13,080 ± 300 yr B.P. (W-3404). It does not seem likely that the underlying flood deposits could be significantly older than the dated peat. Thus, evidence from the Portland delta of Bretz also indicates that the last major scabland flood occurred about 13,000 yr ago.

DISCUSSION

We suggest that the 13,000 yr date be used as an approximate age for the last major flood episode. Although, strictly speaking, the date provides only a younger limit, we believe that it is very close to the actual age of the flood. The postulated and true ages would not differ significantly even if the slack-water deposits in which the ash layers occur were a few tens or a few hundreds of years younger than the flood gravels, since that range is similar to the range of uncertainty of the radiocarbon method itself.

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Because of that uncertainty, however, these and other radiocarbon dates are not likely to answer questions related to the nature and age of sedimentation during and shortly after the flood (Gustafson, 1976; Hammatt *et al.*, 1976; Moody, 1976). But identification and correlation of the various ash layers found on the plateau should provide precise stratigraphic markers to help clarify details of the last scabland flood, as well as earlier floods.

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